Migration distance and the effect of North Atlantic Oscillation on the spring arrival of birds in Central Europe

Dedicated to Professor Karel Hudec in honour of his 80th birthday

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A b s t r a c t. Mean annual first arrival dates (FAD) of 45 migratory bird species recorded in Moravia (Czech Republic, *c*. 49° N) in 109 spring seasons between 1881 and 2007 were correlated with the preceding winter (December to March) North Atlantic Oscillation (NAO) index. The arrival of birds occurred significantly earlier following high NAO winter index values (those result in spring warmer than normal in central Europe) in all short-distance migratory species with a European or North African winter range, whereas the arrival timing did not correlate significantly with the seasonal NAO index in long-distance migrants having sub-Saharan winter range. When the values of Pearson coefficient between NAO and FAD were correlated with the migration distance of all 45 bird species, the correlation was remarkable and significant ($p<0.001$): $r = 0.848$ for the distance to central locations of winter range, and $r = 0.822$ for the northern limits of the wintering area. The migration distance was thus responsible for 68–72 % of variation in the regression of birds' arrival on NAO winter index in central Europe. The data are robust (this is the longest avian phenological record analyzed for correlation with NAO in Europe), and indicate different mechanisms that govern timing between short-distance and long-distance migrants in their departure from wintering areas.

Key words: climate, NAO, phenology, temperature, weather

Introduction

North Atlantic Oscillation (NAO) system is the major promoter of annual weather fluctuation in Europe and eastern North America (W a l l a c e & G u t z l e r 1981, H u r r e l l 1995, Y o o & D ' O d o r i c o 2002). The system can be described quantitatively using monthly, seasonal or annual indices that make possible an analysis of the correlation with other phenomena (S t e n s e t h et al. 2003). A number of papers have reported the effect of NAO on the timing of spring migration of birds (arrival dates: F o r c h h a m m e r et al. 2002, J o n z é n et al. 2002, H u b á l e k 2003, 2004, H ü p p o p & H ü p p o p 2003, S o k o l o v & K o s a r e v 2003, K a ň u š č á k et al. 2004, S i n e l s c h i k o v a & S o k o l o v 2004, V ä h ä t a l o et al. 2004, Z a l a k e v i c i u s et al. 2006) and their breeding phenology (first egg laying date) and productivity (F o r c h h a m m e r et al. 1998, P r z y b y l o et al. 2000, S a e t h e r et al. 2000, B o t h & V i s s e r 2001, M ø l l e r 2002, N o t t et al. 2002, S a n z 2002).

In this study, an unprecedentedly long record (109 years) of avian spring phenology data from Moravia (Czech Republic) has been evaluated for correlation with seasonal NAO index. Several records of FAD published (e.g. S p a r k s & C a r e y 1995, L e h i k o i n e n

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et al. 2004), which covered even longer periods, have not yet been assayed for the effect of NAO. In this paper, the main focus was to analyze whether migration distance between wintering and breeding grounds could affect vulnerability of individual avian species to NAO as a trigger mechanism for spring migration to Central Europe.

Materials and Methods

Bird records

Long-term records of first arrival dates (FAD) of migratory birds in the lowlands of southern Moravia (c. 49° N, 15°–18° E), Czech Republic between 1881 and 1960 were published in a series of phenological yearbooks, based on a network of amateur observers (Niessl 1882–1911, Novák & Šimek 1926, 1930–1938, Zítek 1953–1964); however, the records from 18 years (1907–1922, 1925–1926) were either inaccessible or missing. When the number of FAD records for particular species in a year did not reach three, that year was omitted, and outlier FADs were also neglected. For the years 1961–2007, own observations of FADs combined with mostly unpublished FAD data supplied by a number of experienced Moravian ornithologists were used (V. Hájek, K. Hudec, J. Chytil, P. Macháček and others); some phenological figures from this period were published (Hubálek et al. 2005). In the rook (*Corvus frugilegus*), being only a winter visitor (not a summer resident) in the south Moravian area situated between Břeclav and Brno, date of departure of about half of the wintering population was recorded; all other species were summer visitors, and occasionally overwintering individual birds of certain species (e.g., common starling *Sturnus vulgaris,* greylag goose *Anser anser,* common black-headed gull *Larus ridibundus,* common chaffinch *Fringilla coelebs,* European robin *Erithacus rubecula,* meadow pipit *Anthus pratensis*) were not taken into account. In total, 109 years were covered in this survey, and 45 common bird species with a sufficient number of annual records were selected for the analysis.

Winter ranges of birds

Wintering areas of avian species were consulted with monographs on African birds (Brown et al. 1983, Urban et al. 1986, 1997, Fry et al. 1988, Keith et al. 1992, Fry & Keith 2000, 2004), on birds in Europe including North Africa and the Middle East (Snow & Perrins 1998) and on warblers of the genus *Sylvia* (Shirihai et al. 2001). All species were also checked for wintering areas (ringing recoveries etc.) according to monographs of avian fauna of the Czech Republic and former Czechoslovakia (Hudec 1983, 1994, Hudec & Šťastný 2005).

Northern and southern limits of wintering area for each species were detected as degrees of latitude with precision of 0.5°. In the subsequent calculation of migration distances (one degree equals 111.1 km), we used two characteristics of the winter range: central area as an arithmetic average between the northernmost and southernmost limits of the continuous winter distribution area, and its northern limit. Excluded from the study were common redstart *Phoenicurus phoenicurus* and grasshopper warbler *Locustella naevia* as species each having considerably disjunct wintering range areas – this could present a methodical bias for the study.

North Atlantic Oscillation data

Seasonal (winter – DJFM) NAO index values for particular years between 1881 and 2007 were extracted at http://www.cgd.ucar.edu/cas/jhurrell/indices.html ("winter station based NAO index"). The positive NAO index means that the atmospheric pressure over the subtropical part of the North Atlantic is higher than normal while that over the northern sector of the North Atlantic is lower than normal; this increased pressure difference between the two sectors results in more and stronger storms crossing the Atlantic Ocean and, in turn, causes warm and wet weather (especially in winter) in northern and central Europe. The negative NAO index reflects an opposite pattern of height and pressure anomalies over these sectors; this reduced pressure gradient results in fewer and weaker storms crossing the Ocean, bringing cold air to northern (and central) Europe and moist, often cold air into the Mediterranean (Hurrell 1995). For the Czech Republic, a significant correlation was found between the winter NAO index and local air temperature ($r = +0.78$), but that between this index and local precipitation ($r = -0.30$) was insignificant (Tkadlec 2000).

Statistical analyses

Calendar dates of phenological instants (FAD) were transformed into Julian dates; in leap-years, the sequential numbers were corrected by adding 1, starting from 1st March. Arithmetic average of the FADs (mean arrival date) was calculated in each species for every year. Pearson‘s simple and partial correlation coefficients as well as nonparametric correlation coefficients (Spearman‘s rho, Kendall‘s tau) were calculated and statistical tests done for all comparisons using SOLO 4.0 package (BMDP Statistical Software, Los Angeles, CA).

Results

Eighteen bird species out of the 45 spp. tested revealed a significant ($P<0.05$) negative correlation between the phenological instants and the winter NAO index (Table 1). It means that those species, all representing early-spring short-distance migrants that winter in south-western Europe or in the North-African Mediterranean, arrived in Moravia earlier than normal when the NAO signal was high, while later than normal at negative values of the winter NAO index. On the other hand, the remaining 27 species, having their winter ranges largely in sub-Saharan Africa, either did not correlate with NAO at $P<0.05$ or revealed a positive correlation (river warbler *Locustella fluviatilis*). Using analysis with partial correlation coefficients, differential effect of the variable "NAO" (seasonal NAO index) and "Year" (calendar year) on the avian arrival dates were evaluated by keeping constant Year. The effect of Year, however, was shown to be minor in this dataset (Table 1), causing therefore no problems in the analyses.

The values of Pearson correlation coefficient between NAO and arrival timing in Table 1 were then compared with the migration distance of all 45 bird species. Simple correlation was remarkable and significant ($P<0.001$): $r = 0.843$ for the central locations of winter range, and $r = 0.814$ for the northern limits of the winter areas. Analogical values for partial Pearson correlation (adjusted for variable Year, i.e. detrended), were 0.848 and 0.822, respectively. The avian migration distance is therefore responsible for 68–72 % of variation in the regression of birds' arrival on NAO winter index in Central Europe. Fig. 1 shows this regression of Pearson index (partial correlation, adjusted for variable Year), correlating seasonal NAO index and arrival data in Moravia of the 45 avian species (y-axis),

Table 1. Spring phenology instants of 45 migratory bird species in Moravia (49º N), 1881–2007, with the Pearson correlation coefficient *r* values between the avian first arrival dates (FAD) and winter NAO index, and the migration distance (in degrees of latitude; one degree equaling 111 km). The *r* values printed in bold are significant ($P < 0.05$).

Bird species	No. years recorded	Mean FAD (Julian date)	Simple correlation: Arrival vs. NAO	Partial correl.: Arrival vs. NAO (adj. YEAR)	Distance (º) to centre of Winter range	Distance (º) to north limits of Winter range
Alauda arvensis	107	59.4	**–0.3505**	**–0.3457**	12	5
Sturnus vulgaris	108	61.5	**–0.3734**	**–0.3531**	12.5	3
Anser anser	73	61.8	**–0.3326**	**–0.3186**	7.5	–4
Corvus frugilegus	41	68.8*	**–0.4757**	**–0.4628**	5	–8
Turdus philomelos	83	72.0	**–0.3120**	**–0.2849**	14	3
Vanellus vanellus	104	72.6	**–0.3310**	**–0.3134**	9.5	–1
Larus ridibundus	72	73.0	**–0.3042**	**–0.2824**	24	–8
Motacilla alba	100	73.3	**–0.2038**	–0.1852	30	6
Fringilla coelebs	72	73.8	**–0.2528**	**–0.3111**	10	–2
Anthus pratensis	49	74.7	**–0.2792**	–0.2623	15	–3
Columba palumbus	83	76.6	**–0.3615**	**–0.4252**	12	2.5
Erithacus rubecula	72	79.7	**–0.2813**	**–0.2516**	11.5	2
Scolopax rusticola	50	82.5	**–0.3575**	**–0.4555**	8.5	–2
Phylloscopus collybita	56	82.5	**–0.4120**	**–0.3965**	27	3
Phoenicurus ochruros	79	82.8	**–0.2779**	**–0.2610**	19.5	3
Saxicola torquatus	44	83.5	**–0.3186**	**–0.3055**	22.5	3
Remiz pendulinus	43	88.8	**–0.4165**	**–0.4047**	11	1
Serinus serinus	56	90.1	**–0.2904**	**–0.2608**	13.5	6
Ciconia ciconia	90	93.7	–0.0890	–0.0996	45	13
Sylvia atricapilla	64	95.9	–0.1674	–0.1223	33.5	4
Phylloscopus trochilus	51	97.0	–0.1562	–0.1158	58.5	34
Motacilla flava	47	98.9	–0.0778	–0.1496	51	19
Anthus trivialis	67	100.2	+0.1906	+0.1498	52	32
Hirundo rustica	104	102.0	–0.0386	+0.0330	52	21
Upupa epops	76	103.7	–0.2009	–0.1825	39.5	29
Jynx torquilla	83	104.6	–0.0750	–0.0419	41	33
Ficedula albicollis	56	106.0	–0.0436	–0.0493	57.5	45
Sylvia curruca	65	106.1	–0.2046	–0.1893	30.5	18
Acrocephalus schoenobaenus	40	108.8	–0.0878	–0.0458	56.5	32
Delichon urbicum	81	109.8	+0.1551	+0.1491	56	29
Locustella luscinioides	29	110.2	–0.0884	–0.0898	38	32
Phylloscopus sibilatrix	46	111.9	–0.2542	–0.2310	46.5	39
Cuculus canorus	109	112.4	–0.1298	–0.1279	59.5	36
Luscinia megarhynchos	76	112.8	–0.1744	–0.1448	45	33
Riparia riparia	38	112.9	–0.1725	–0.2231	53	27
Streptopelia turtur	78	115.1	–0.0264	+0.0082	37	30
Acrocephalus scirpaceus	27	118.2	–0.0679	–0.0672	50	32
Acrocephalus arundinaceus	41	119.9	+0.2020	+0.2305	56	32
Apus apus	72	120.2	–0.1030	–0.0509	61	43
Oriolus oriolus	84	124.7	+0.0022	+0.0023	62.5	42
Hippolais icterina	76	125.7	+0.0250	–0.0067	64.5	49
Muscicapa striata	52	125.8	+0.2146	+0.1825	59	35
Locustella fluviatilis	35	126.9	**+0.3692**	**+0.3639**	68	62
Lanius collurio	68	126.9	+0.1098	+0.0932	64	47
Acrocephalus palustris	30	129.0	+0.1259	+0.2127	70	57

* mean date of departure of about half of wintering population from the recording area (South Moravia).

on the mean migration distance between central wintering area of particular bird species and recording area – 49º N (x-axis) graphically. The regression is approximately linear, but significant (P < 0.05) values were found only for r > |0.25| (on y-axis). However, there is a statistical problem with the non-normal distribution of the migraton distance data set: it reveals in fact two frequency peaks (one for short-distance migratory birds, and another for long-distance migrants): the kurtosis, normality, and D'Agostino-Pearson omnibus tests all showed a significant deviation from normality. We therefore used non-parametric correlation coefficients of Spearman (ρ – rho) and Kendall (τ – tau) but they confirmed the previous results. For instance, the values of ρ for correlation between Pearson's partial correlation coefficient FAD vs. NAO and migration distance from central wintering area to Moravia was 0.867 while that for distance from the northern limits of wintering area 0.822, both values being significant (P < 0.001). Analogical τ values were 0.675 and 0.621, respectively, both highly significant. In addition, we tested the relationship separately for short-distance (Eurasian skylark *Alauda arvensis* to European serin *Serinus serinus* in Table 1, 18 spp. in total) and long-distance (willow warbler *Phylloscopus trochilus* to marsh warbler *Acrocephalus palustris* in Table 1, 25 spp.) migrants, using Pearson's r (because both data sets did not reveal a significant deviation from normal distribution in migration distance using skewness, kurtosis, normality and D'Agostino-Pearson omnibus tests): the r values between detrended correlation NAO *vs* FAD and the central migration distance were 0.487 (P < 0.05) and 0.561 (P < 0.01) for short-distance and long-distance spp., respectively. The migration distance was thus responsible for 24% and 31% of variation in the regression of arrival of short-distance and long-distance bird species, respectively, on NAO winter index.

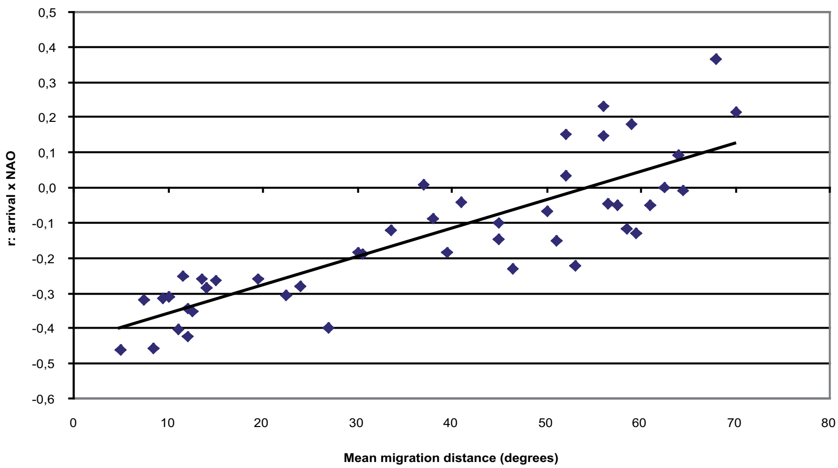

Fig. 1. Scatterplot of relationships between (i) distance of mean central wintering areas to recording area (49º N: x-axis) in degrees of latitude (one degree equaling 111.1 km) in 45 migratory bird species, and (ii) partial correlation (adjusted for Year) between their mean arrival dates in Moravia and corresponding NAO winter index (y-axis). Only the r values > |0.25| have been found to be significant (P<0.05).

Discussion

In general, several confounding factors could affect reliability of FAD data. For instance, S p a r k s (1999), T r y j a n o w s k i & S p a r k s (2001), T r y j a n o w s k i et al. (2002, 2005) and L e h i k o i n e n et al. (2006) revealed that apparent fluctuations in migration phenology can result from changes in: (i) population size of particular bird species, (ii) the bird species detectability, or (iii) recorders' skill and effort (i.e., the number of observers and the time spent). In our study, we only followed common bird species whose population sizes did not change considerably with time. The only exceptions were the species with population on decline in Moravia (northern lapwing *Vanellus vanellus, Larus ridibundus* and Eurasian hoopoe *Upupa epops*), whereas those increasing were *Ciconia ciconia, Luscinia megarhynchos* and Eurasian blackcap *Sylvia atricapilla* (Š ťa s t n ý et al. 2006). However, the results yielded in these species are in line with the general conclusion that long-distance migratory species are not affected significantly by NAO activity, in contrast to short-distance migrants, which was also found in two previous Moravian studies (H u b á l e k 2003, 2004).

The length of the time series analyzed in this study of bird FAD (1881–2007, with a total of 109 years) as affected by NAO is, to our knowledge, unprecedented for Europe. In six species (*Alauda arvensis, Sturnus vulgaris, Vanellus vanellus,* white wagtail *Motacilla alba,* barn swallow *Hirundo rustica,* common cuckoo *Cuculus canorus*) the record encompassed at least 100 years, and in majority of the other species it typically covered periods between 40 and 80 years. In addition, only common, well-known, and easily detectable avian species were taken into account in this survey. This gives this study a great robustness and reliability.

The seasonal winter NAO index did not correlate significantly with the arrival of a vast majority of long-distance migratory species wintering in tropical and southern Africa; only one of 27 of those trans-Saharan migrant species revealed a significant (but positive) correlation. Timing of the departure of birds from the sub-Saharan winter grounds is obviously unaffected by the weather system fluctuation at northern Atlantic latitudes (B o t h & V i s s e r 2001). On the other hand, significant inverse relationship was found between the arrival of all 18 short-distance migrants tested (wintering in Europe or in North Africa) and the winter NAO index, indicating that a higher than normal air pressure difference over the North Atlantic during the winter/spring (especially in February and March) determines an earlier than normal arrival of these birds in Central Europe. These results correspond well with the studies of N o t t et al. (2002) in North America, J o n z é n et al. (2002) in east Sweden, R a i n i o et al. (2006) in South Finland, and Z a l a k e v i c i u s et al. (2006) in Lithuania, as well as with previous papers from the Czech Republic (H u b á l e k 2003, 2004, H u š e k & A d a m í k 2008: red-backed shrike *Lanius collurio*) and Slovakia (K a ň u š č á k et al. 2004: *Locustella fluviatilis*). In Poland, T r y j a n o w s k i et al. (2002) observed a more pronounced trend to earlier spring arrival in short-distance migrants than in long-distance ones. Nevertheless, the results of our survey are not in accord with studies of F o r c h h a m m e r et al. (2002), H ü p p o p & H ü p p o p (2003), V ä h ä t a l o et al. (2004), J o n z é n et al. (2006), and S o k o l o v & K o s a r e v (2003) who found in Norway, Helgoland (Germany), southern Scandinavia and Courish Spit (West Russia, Baltic), respectively, no significant difference in the effect of NAO on spring arrival between long-distance and short-distance migrants. However, a lower number of species of each group and much shorter records were tested in the latter studies, interestingly all originating only from the "warming" period that started after 1960, while periods with a decreasing or stable trend of temperature were not covered (cf. L e h i k o i n e n et al. 2006 for this effect). Moreover, not FAD but mean spring passage times were recorded in Helgoland, Scandinavia and Courish Spit. It was found in the latter location that while the 5th percentile population arrival dates (which are close to FAD) for song thrush *Turdus philomelos* correlated significantly with March NAO index in 1958–2002 ($r = -0.379$), the median (i.e., the 50th percentile) arrival dates did not; identical results were presented for redwing *Turdus iliacus* in the same area (Sinelschikova & Sokolov 2004). Also Vähätalo et al. (2004) observed disagreement between FAD and median arrival dates in NAO relationships of some bird species in Finland. Phenology results based on median of arriving population (or mean spring passage time) may thus significantly differ from those based on FAD (Lehikoinen et al. 2006).

An additional support for the effect of migration distance on the vulnerability of bird species to global Atlantic weather conditions (winter NAO) are the results of a previous cluster analysis study showing that all species which are short-distance migrants (wintering in Europe or in the Mediterranean including North Africa) clustered together in their longitudinal migration timing, while the remaining species, having their winter ranges largely in sub-Saharan Africa, grouped separately as a number of smaller 'migrons' (Hubálek 2005). Gordo et al. (2005) demonstrated that the spring migration timing (the departure from Africa, and FAD in Spain) of trans-Saharan migrants *Cuculus canorus,* common swift *Apus apus, Upupa epops,* common house martin *Delichon urbicum* and common nightingale *Luscinia megarhynchos* was affected by the climate and weather conditions (especially precipitation) prevailing in their African winter quarters rather than by the global weather (determined largely by winter NAO) on their European breeding grounds.

The positive winter NAO index values mean a milder (warmer and drier) winter and spring in Europe (Hurrell 1995, Hurrell et al. 2003). This leads to an advanced invertebrate abundance in spring which might benefit short-distance migrants more than long-distance migratory species (Nott et al. 2002). The marked effect of NAO on waterbirds wintering in southern and western Europe (in this study: *Anser anser, Larus ridibundus, Vanellus vanellus*) is attributable to earlier ice break-up of lakes and rivers in Central Europe due to direct effect of a positive phase of seasonal NAO (Yoo & D'Odorico 2002, Rainio et al. 2006).

An important finding of this study is that migration distance is responsible for as much as 70% of variation in the relation between FAD and NAO winter index (*r*) in Central Europe – i.e., the longer the northward migration route, the lesser the effect of NAO on the migration timing of birds. However, although the regression is approximately linear, as significant absolute values of the correlation *r* were found only those greater than 0.25, in fact corresponding to short-distance migrants only. The data are robust and reliable, and indicate the role of different factors affecting timing in short-distance and long-distance migrants in their departure from wintering areas. It is most probable that the weather in wintering quarters, especially the precipitation affecting food availability (for the build-up of reserves for migration), has a stronger influence on the migration behaviour of long-distance migrants than the weather conditions in the western Palaearctic determined by NAO (Gordo et al. 2005).

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